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Research Article

Pausing and sentence stress in children with dysarthria due to cerebral palsy

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Short Title: Pausing in children with cerebral palsy

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Abstract

Introduction: Children with dysarthria due to cerebral palsy (CP) can experience problems manipulating intensity, fundamental frequency and duration to signal sentence stress in an utterance. Pauses have been identified as a potential additional cue for stress marking, which could compensate for this deficit.

Objective: This study aimed to determine whether children use pauses to signal stress placement, and whether this differs between typically-developing children and those with CP.

Methods: Six children with CP and eight typically developing children produced utterances with stress on target words in two different positions. Pauses before and after the stressed target words were analyzed in terms of number, location and duration.

Results: Results showed that both groups inserted pauses into their utterances. However, neither group used pause location or duration in a systematic manner to signal the position of stressed words.

Conclusions: The results suggest that pausing was not used strategically by either group to signal sentence stress. Further research is necessary to explore the value of pausing as a cue to stress marking in general and as a potential compensatory strategy for speakers with dysarthria.

Introduction

The highlighting of words within utterances, also referred to as *sentence stress*, is crucial to effective spoken communication. In conversations, it serves an important linguistic-pragmatic function. By emphasizing new or important information in the speech stream the speaker directs the conversation partner to the most relevant part of the utterance, that way structuring information in discourse [e.g. 1, 2]. It is well-established that in West-Germanic languages including English sentence stress is marked by increases in duration and intensity, as well as an expanded fundamental frequency (F0) range on the highlighted word [e.g. 3-5]. In parallel with studies investigating segmental speech development in children, researchers have also focused on the emergence of prosodic patterns. Evidence suggests that children speaking West-Germanic languages can reliably control duration, intensity and F0 to signal sentence stress from about four to five years [e.g. 6-10]. Production consistency and stability continues to develop beyond this age [8, 11].

In addition to the above three acoustic parameters, there is evidence that pausing might be an additional parameter that can be used to mark sentence stress in an utterance. Dahan and Bernard [12], Gee and Grosjean [13], and Swerts and Geluykens [14] demonstrated that adult speakers used pauses in discourse to either introduce new information or highlight specific information. They did this by inserting pauses and/or increasing pause duration before the highlighted word. Dahan and Bernard [12] furthermore showed that listeners benefitted from these cues as the presence of pauses before the stressed word led to an increased perception of emphasis.

Children's pausing patterns are less well-researched even though children tend to pause more frequently than adults [15]. The few studies investigating the possible role of pausing for discourse structuring purposes suggest an adult-like use of pausing in the marking of new information in discourse [15-17]. Specifically, Esposito [16] found that nine-year old Italian children, similar to adults, pause to convey new information, whereby longer pauses were associated with marking new information and shorter pauses with already given information. Redford [17] also observed that English-speaking 5-year olds paused longer before new information, and concluded that the children were aware of the role of pausing as a means of discourse marking. Romøren and Chen [15] systematically investigated the link between pausing and sentence stress in 5-year old Dutch children. The authors elicited a range of sentences with varying sentence stress structures. They further found that pauses before stressed words were significantly longer than pauses occurring before the unstressed counterpart of the same word. In addition, the Dutch children used pausing more consistently than adults, suggesting that they exploited pausing more systematically to stress words in utterances.

The notion that pausing could potentially function as an additional indicator to sentence stress alongside manipulations of duration, intensity and F0 is relevant from a clinical perspective. Both adults and children with dysarthria are known to experience problems with stress production due to poor control of the above mentioned parameters. This includes children with cerebral palsy [18], adults with Parkinson's disease [19, 20], adults with ataxia [21-23] and adults with brain injuries [24-26]. Therapeutic interventions focusing on strategies for more effective stress production through modifying duration, intensity and F0 have yielded inconsistent results [27-29]. Frequently, speakers are limited in their ability to increase performance levels in e.g. intensity or F0, or control parameters sufficiently to achieve the precise coordination that is required for successful stress marking. A strategy that relies on a decrease in speech activity, i.e. silence in the form of a pause, may therefore represent a viable compensatory strategy to mark sentence stress. However, there is currently insufficient information as to how children and adults with dysarthria use pausing for stress marking. An investigation of pausing in contrastive stress tasks in a group of ten adults with dysarthria due to hereditary ataxia showed that half of these speakers used pauses systematically to signal sentence stress by placing pauses mostly before, but also following the stressed word [22]. Similar findings were reported in a single case study on another speaker with ataxic dysarthria due to a head injury [28]. These studies potentially indicate that these speakers were using pausing to spontaneously compensate for the impaired ability to manipulate other acoustic correlates of sentence stress. Given the potential benefits of pause insertion for stress marking in adult populations, and the fact that Romøren and Chen [15] reported that typically-developing children used pauses systematically to mark stressed words, the role of pauses for sentence stress marking in younger speakers should be explored further. This may be particularly useful to investigate in speakers who are affected by dysarthria such as children with dysarthria due to cerebral palsy (CP).

CP is an umbrella term for a group of non-progressive disorders of movement and posture, which are caused by damage to the developing brain [30]. It is the most common cause of developmental motor problems [31], with recent population-based investigations suggesting that between 30-90% of all children with CP may present with dysarthria [32-34]. Common speech characteristics associated with dysarthria due to CP are shallow, irregular breathing, reduced vocal quality, inappropriate loudness levels, reduced pitch variation, hypernasality, slower speech rate and imprecise articulation [35-39]. These speech features can affect sentence stress production, and a recent study by Kuschmann and Lowit [18] investigating children's ability to manipulate acoustic parameters to signal stress showed that the children with CP and dysarthria were not as effective as typically-developing children [18]. The authors found that children with CP used a more limited set of acoustic parameters than their matched peers to mark sentence stress. Specifically, the children with CP were able to manipulate duration but not intensity and F0 of stressed words. This led listeners to being less successful in identifying the highlighted word. However, no study to date has investigated the use of pauses during stress marking in this speaker population. We therefore currently do not know whether children make use of pausing to mark sentence stress. However, information on this will be vital to understand the potential clinical benefits of pausing for children with CP and dysarthria.

Aim of the study

This study therefore aimed to investigate whether children with CP and dysarthria as well as typically-developing children use pauses to signal sentence stress. Specifically, the present study aimed to determine whether both groups systematically employ pausing to mark sentence stress within an utterance, as reflected by the number of pauses, their position (before or after the stressed word) and duration.

Methods

This investigation used sentence stress production data that was collected as part of a larger study investigating prosodic abilities in children with dysarthria and CP. Results of the participants' stress patterns focusing on duration, intensity and F0 have previously been reported in Kuschmann and Lowit [18]. Ethical approval to conduct the study was obtained from the Strathclyde University's Ethics Committee. Written informed consent was gained either from parents or children, depending on age.

Participants

Eight children and young people with dysarthria and cerebral palsy (CP) and eight age, gender and dialect matched typically-developing peers (TD) participated in the original study. For the pausing analyses the data of two participants (CP5 and CP8) were excluded as they were either unable to complete the sentence stress production task (CP8), or did not consistently produce the target materials in a carrier sentence (CP5). This did not allow comparisons with the utterances produced by the other participants. All TD participants' productions were eligible for inclusion. Despite the resulting difference in group size, this paper reports on the data of all TD children to have a more representative control sample (cf. table 1; CP: 4 boys, 2 girls, range: 7-18 years, mean = 11.8 years; TD: 6 boys, 2 girls, range: 7-20, M = 11.8 years).

For all participants, hearing and vision was normal or adjusted-to-normal, and cognitive skills were appropriate to follow task instructions. The TD children had no history of communication disorders and no known developmental disorders. Three children with CP had been diagnosed with dyskinetic CP, two with spastic-type CP, and one with ataxic CP. All were diagnosed with dysarthria by speech and language therapists and had received speech and language therapy in the past. Speech intelligibility was measured using the CSIM (Children's Speech Intelligibility Measure [40]), indicating a mild to moderate range of dysarthria severity (cf. table 1).

--table 1 about here--

Materials

To investigate children's ability to mark sentence stress a task containing short nominal phrases (NPs) was designed [18]. A set of two bi-syllabic pre-nominal adjectives (colour – yellow, orange) and five mono-syllabic nouns (animal – cow, dog, goat, goose, horse) were combined to produce ten NPs, e.g. yellow dog. The use of short target structures aimed to reduce the impact of respiratory control issues in the children with dysarthria. Stress was elicited on the adjective (e.g. YELLOW dog) and on the noun (e.g. yellow DOG), resulting in 20 phrases per participant, and 280 phrases across both groups. This set formed the basis for the subsequent pausing analyses.

Procedures

A picture-based question-answer paradigm, presented in Microsoft Office PowerPoint®, was employed to elicit the two different stress conditions. Participants were first shown pictures that prompted stress on the adjective (word 1); followed by the pictures that required stress on the animal (word 2). When describing the pictures, the participants were asked to embed the phrases in a carrier sentence ("The *yellow cow* jumped out.").

Each participant was tested individually in a quiet room in their homes, with the first author explaining and guiding the children through the test. Audio recordings were made using a portable Edirol R-09HR MP3 recorder with a 44.1 kHz sampling rate and 16 bit accuracy. Recording settings, instructions and experimental design were the same for each participant to ensure consistency across recordings. The presentation started with an introduction to the task and practice stimuli, before proceeding to the actual experiment. Participants worked through the presentation at their own pace with pictures being shown one at a time.

Data selection

The elicited phrases were prepared for pausing data analysis using Praat speech analysis software (version 5.3.39 [41]). Data selection followed the strict process outlined by Romøren and Chen [15] on typical-developing speech to ensure a controlled experimental environment with comparisons being made across the same phrasal structures. Following this procedure, participants' responses were excluded if answers contained non-target words (e.g. duck instead of goose) or additional words, if nouns were replaced by pronouns (e.g. the yellow one), as well as in instances of hesitations, self-repair or stuttering. Additionally, due to the nature of the children's speech difficulties in this study, productions were not included if phonetic deviations were present in the target structures. Based on these exclusion criteria, the final data set available for the analyses of pauses consisted of 221 phrases. Average response inclusion rate was 84% (range: 45-100%) for the TD children, and 72% (range: 50-100%) for the children with CP.

Data annotation and analysis

The selected data was segmented into words based on waveform and formant changes in the spectrogram [42]. Segmentation conventions were established to ensure consistency, e.g.

onset plosives were segmented directly before the burst. Data was annotated on three different tiers (cf. figure 1):

(1) orthographic annotation of the utterance including pause position (1 = pause between determiner and adjective, 2 = pause between adjective and noun, 3 = pause between noun and verb auxiliary)

(2) annotation of the position of the stressed word (e.g. 1-0, with the first number denoting word position, i.e. word 1 or 2 of NP) and the second number denoting stress (0 = unstressed, 1 = stressed)

(3) comments, if required

--insert figure 1 about here--

Following Romøren and Chen [15], a pause was defined as a between-word interval of any duration with either no or insignificant amplitude. That is, pauses were annotated using a strictly phonetic approach, combining Praat's automatic silence detection function (silence threshold 35dB, silence duration 20ms) with manual visual inspection. A Praat script was then employed to automatically extract pause duration from each labelled silence interval. Output data was inspected and cross-checked to detect potential tracking and measuring errors of the software.

Based on the above annotation, *number* and *duration of pauses* were determined and statistically analysed in relation to their *position* (P1 – after determiner, P2 – after adjective, P3 – after noun) and *stress condition* (C1 – adjective stressed, C2 – noun stressed). Statistical analyses included group comparisons for both measures, i.e. number and duration of pauses, between TD children and children with CP using the Mann-Whitney-U-Test as well as within-group comparisons using the Wilcoxon Signed Ranks Test.

As per table 1, there is a bimodal distribution of age in our data, i.e. younger participants (6-8 years of age) and older participants (14-20 years of age). Splitting the data into those two groups, however, would result in too low participant numbers to allow for a meaningful statistical analysis and interpretation of the data, in particular for the children with CP. The data was therefore collapsed into one group, with all results being cross-checked for age effects when interpreting results.

Results

Number and position of pauses

Table 2 provides an overview of the individual results with regard to the mean number of pauses per utterance across all three pause positions investigated. For the TD children the mean number of pauses per utterance was 1.35, and for the children with CP 1.80. The difference was not significant (U=14.500; p=0.220). As can be seen from the table, half of the CP group fell within the range of the TD children, with a further three children showing values above that range.

--table 2 about here--

The distribution of the observed pauses for each group and pause position is displayed in table 3. Initial group comparisons showed no significant differences between groups regarding pause placement (P1: U=68.000, p=0.188; P2: U=92.000, p=0.852; P3: U = 68.000, p=0.193), suggesting that both groups paused similarly often in the three positions investigated. Subsequent within group analyses, however, found that, across all productions, each group placed significantly fewer pauses at position 1, i.e. between the determiner and the adjective, than at positions 2 and 3 further on in the utterance (TD: P1 vs P2: Z=-3.519, p=0.000, P1 vs P3: Z=-3.297, p=0.001, P2 vs P3: Z=-0.070, p=0.944; CP: P1 vs P2: Z=-2.944, p=0.003, P1 vs P3: Z=-2.601, p=0.009, P2 vs P3: Z=-1.071, p=0.284). Further within-group analyses comparing the number of pauses in each position across stress conditions (C1, and C2) revealed no significant effects in either group (TD: P1: Z=-1.782, p=0.075; P2: Z=-

0.943, *p*=0.345; P3: *Z*=-1.352, *p*=0.176; CP: P1: *Z*=-0.135, *p*=0.893; P2: *Z*=-1.826, *p*=0.068; P3: *Z*=-1.461, *p*=0.144).

Combined, these results suggest that the children did not use pause placement to mark the position of the stressed word in the utterance. Inspection of the individual data suggests that this was also the case for the three children with CP who produced higher numbers of pauses than the TD group.

--Insert table 3 about here--

Duration of pauses

Table 4 displays individual results on pause duration across all three pause positions, showing that all children with CP - except CP7 - had mean pause durations above the range of the TD children. Statistical test results for the group comparisons for each pause position confirmed this observation (P1: *U*=134.000, *p*=0.019; P2: *U*=1261.500, *p*=0.000; P3: *U* = 1117.000, *p*=0.000, see also figure 2).

--insert table 4 about here--

--insert figure 2 about here--

Subsequent within-group analyses established that stress condition was not a factor that influenced pause duration in the different positions for either group (TD: P1: Z=-0.415, p=0.678; P2: Z=-0.911, p=0.362; P3: Z=-0.370, p=0.712; CP: P1: Z=-0.153, p=0.878; P2: Z=-0.249, p=0.804; P3: Z=-1.143, p=0.253). Separate within-group analyses to detect potential differences between pause positions showed that for the TD group P3 pauses were significantly longer than those in P2; however, the remaining comparisons were not significant (TD: P1 vs P2: *Z*=-1.381, *p*=0.167, P1 vs P3: *Z*=-1.045, *p*=0.296, P2 vs P3: *Z*=-4.652, *p*=0.000). A similar, albeit smaller effect was observed for the children with CP, with only a trend for P3 pauses to be longer than those in P2 (CP: P1 vs P2: *Z*=-0.456, *p*=0.648, P1 vs P3: *Z*=-1.186, *p*=0.236, P2 vs P3: *Z*=-1.864, *p*=0.062). These findings suggest that neither the TD children nor the children with CP manipulated pause duration to signal the position of the stressed word within the phrase.

Discussion

This study investigated whether children with dysarthria due to CP as well as TD children used pausing to signal the position of stressed words in short utterances. Findings revealed that neither group used pause placement or pause duration to mark the stressed word within the utterance. Consequently, it can be concluded that the children in this study did not employ pausing to mark the position of the stressed word within an utterance.

Number of pauses and pause placement

The available research into pause placement for discourse structuring purposes has shown that children insert pauses before new information [15, 16] comparable to adult speakers [12, 13, 14]. Similar pausing behaviours were observed in adults with motor speech disorders [22, 28], suggesting that the use of pauses can be a discourse marker for new information in disordered speech. However, in our study a general positional effect was evident with more pauses towards the end of the phrase rather than before new information. This finding indicates that in our group of children pauses were not used as a main marker for new information. It is important to note though that both groups of participants paused frequently. This is in line with findings from Romøren and Chen [15] on high pause frequency in typically-developing child speech and suggests that the frequent pausing in our sample was not a unique feature of dysarthric speech. However, despite the lack of a significant difference between the two groups regarding pause numbers, we observed that half of the children with CP fell within the range of the TD children for number of pauses, whereas the other half showed values above that range. This suggests a potential influence of dysarthria on pausing for these speakers. An inspection of the children's dysarthria severity level as well as age and type of CP did not reveal a specific pattern that could explain the higher use of pauses in these children. For instance, CP1's number of pauses fell within and CP2's above the range of the TD children, whilst both were diagnosed with mild dysarthria. At the same time, CP3, whose speech was moderately affected, had fewer pauses than both CP1 and CP2. Similarly, type of CP did not explain the observed performance either. Of the three children with CP, whose number of pauses was above the range of the TD children, one had ataxic CP, one had spastic CP and one had dyskinetic CP. Age did not seem to be a relevant factor either to account for the differences, with both younger (CP2 and CP6) and older children (CP4) producing more pauses. We therefore assume that factors beyond age, type of CP and dysarthria severity - such as linguistic and prosodic constraints -, may have a role in explaining some of our observations on pause placement.

Research into the role of syntactic structure on pausing in adult speech found that pauses frequently occur at major syntactic boundaries [e.g. 43, 44]. For child speech, however, Redford [17] observed more pauses in syntactically unexpected locations than in adult speech. This observation aligns with our findings of some pauses being placed e.g. following the utterance-initial determiner or between the adjective and noun. Redford [17] argues that these unexpected pauses may indicate that children have yet to fully acquire knowledge on when to pause and how to coordinate speech breathing with linguistic content. This assumption might explain why we observed pauses across all three positions investigated. Having said that, we also found a position effect across both groups, with more pauses being placed towards the end of the NP (P2 and P3) than at P1. This finding could suggest that neither group paused randomly, adhering to prosodic constraints expected in typical adult speech [e.g. 45, 46]. For example, pausing directly after a determiner in utterance-initial position is undesirable from a prosodic point of view as function words are less likely to attract pitch accents than content words unless they are stressed [e.g. 47-49]. A determiner - if followed by a pause signalling an Intonation Phrase boundary - will therefore have to be assigned a pitch accent, which may alter the pragmatic meaning of the utterance, and may result in unusual or unexpected stress patterns. From this point of view, our results could suggest that both groups in our study successfully adhered to rules of intonational well-formedness by placing fewer pauses in P1. This conclusion contradicts Redford's [17] assumption that children have yet to fully acquire knowledge on when to pause. However, it is important to acknowledge though that our participants were older than those in the Redford study [17]. In summary, neither participant group appeared to use pauses strategically to mark sentence stress, but both showed signs of adherence to prosodic wellformedness rules by predominantly placing them towards the end of the utterance.

Duration of pauses

Similar to pause placement, studies on pause duration in adult speech show that speakers increase pause duration before introducing new information in spoken discourse [12, 13, 14]. Research on child speech in this area is limited, but the available evidence suggests that children show adult-like pausing behaviour by pausing longer before words that introduce new information [15, 16, 17]. Once again, this pattern could not be observed in our data, suggesting that our participants did not use pause duration to signal new information in discourse.

We did observed, though, that children with CP paused for longer in each position than the TD children. Pause duration and articulation rate form the basis for the measure of speech rate, which is frequently reported to be reduced in children with CP [e.g. 36, 39, 50]. As reported in [18], the current group of CP children produced longer speech segments during sentence stress task than the TD children, indicative of reduced articulation rate. However, there was no clear relationship between the children's word durations and pause length, and similar to our finding for number of pauses, dysarthria severity and type of CP did not appear to be determining factors for pause duration either. Specifically, CP2 who had a mild level of speech impairment produced longer pauses than CP3, who had the lowest intelligibility score of the group. Type of CP did not reveal any particular impact on pause duration either, as two participants with dyskinetic CP (CP6 and CP7) had both the longest and the shortest pause times respectively (cf. table 4). Age did not appear to be a determining factor either. Whilst CP6, one of the younger speakers, produced the longest pause times, CP2, another young participant, produced pauses that were comparable in length to CP3, who was part of the older age group. It thus appears that pause duration, similar to pause placement was determined by other factors than those captured by the current evaluation tools. However, it is important to point out that participant numbers in each group may have been too small to detect potential patterns, and analyses on larger cohorts will be beneficial to establish to what extent our findings are reflective of the wider CP population.

Although we observed group differences in our data in terms of overall duration of pauses, analyses of the effect of stress condition on pause duration did not yield significant results. As outlined above, with regard to the TD children, this result does not support previous findings of a strong link between pause duration and the position of the stressed target word within an utterance reported by Romøren and Chen [15]. Our data showed a general positional effect for both groups that appears to be unrelated to the stress condition. Specifically, both groups had significantly longer pauses following the noun (P3) compared to the adjective position (P2). This appears intuitive as pauses following the noun would be at the end of the NP and, hence, in a position that could be considered a major prosodic and syntactic boundary. One could further argue for the presence of a cognitive boundary after the noun, as this was the end of the target NP where the children had to pay attention to their output as the remainder of the utterance consisted of the carrier phrase that was constant across all utterances.

Although our data does not support previous observations of a link between pause duration and stress position [15], the absence of a consistent link between pausing and sentence stress in our data does not necessarily imply that pausing is not available to the children as an additional parameter to mark stress. It is possible that pausing may not have been employed by our groups for various reasons including differences in sentence material, children's age and the language investigated. For instance, Romøren and Chen [15] investigated Dutch-speaking children, using a larger variety of sentence materials to elicit stress in different utterance positions. Also, the phrases produced by the children in our study were shorter and syntactically and prosodically less complex to accommodate the potential motoric restrictions in the children with CP. The differences in syntactic and prosodic complexity might have had an impact on the potential relevance of pausing as a cue to stress. In addition, Romøren and Chen's [15] participants were five years old, and thus younger than the children in our study, who were at least seven years of age. Romøren and Chen [15] argued that the children's more robust and consistent use of pausing to mark stress - compared to adults - might be partly due to the fact that their access to pitch accent cues for the purposes of marking stress is still developing. This might not be the case for the older children in our study, who may have already exhibited adult-like patterns to marking stress. Support for this assumption comes from their use of acoustic parameters to mark stress [18], which showed that the TD children employed a combination of duration, intensity and F0 to mark sentence stress - just as adults would do -, and our perceptual data indicates that this strategy was successful in the majority of utterances. As a result, pausing may not have been required as an additional parameter to marking stress. However, whilst this might be plausible for the TD children, it is currently unclear why the children with CP did not exploit these cues to the same extent, as they experienced problems using intensity and F0 to signal stress, with only duration being used in a comparable way to the TD group [18].

Further research is clearly needed to better understand the potential role of pausing as a meaningful marker of sentence stress in TD children as well as children with CP and dysarthria. As part of this, it should be explored in perception studies whether listeners can use pausing as a cue to stress marking, and thus whether this could be a helpful strategy for some children to communicate pragmatic intent.

Limitations

Whilst our study has revealed important insights into pausing behaviours in children with dysarthria and CP and their TD peers, limitations exist. Our study reports the results of a small number of children with typical and atypical speech, and as a result generalisations based on our findings are not possible. Small sample sizes are an inherent issue when working with children with dysarthria, often in combination with heterogeneous speaker characteristics in terms of age, CP type and dysarthria severity. Ideally, further research with larger sample sizes and comparable individual speech characteristics is required to get a fuller understanding of potential systematic patterns. Additionally, our data was originally designed to investigate the use of duration, intensity and F0 in the production of sentence stress in children with CP and dysarthria. Whilst the data lent itself to investigate pausing as an additional potential stress marker, it was not specifically designed with syntactic complexity in mind. This needs to be considered when putting current findings in context.

Clinical implications and Conclusions

This study on pausing patterns in children with dysarthria CP and their TD peers has shown that neither group signalled the position of stressed words in short utterances through pause placement or duration. Our findings therefore do not suggest that pausing was strategically employed as an additional cue to marking sentence stress by our cohort, but given the limitations of this study discussed above, a larger study using more targeted speech material might be able to throw further light on this question. Additionally, structured experiments that require speakers to place pauses in specified locations, combined with listener evaluations could help to demonstrate whether pausing could be employed as an overt strategy to mark stress more successfully. This could aid the listener to locate highlighted information, in line with Dahan and Bernard's (1996) finding, and might furthermore help the speaker to modulate the primary stress markers more effectively.

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Statement of Ethics

The research reported here complies with the guidelines for human studies. Ethical approval to conduct the study was granted by the University Ethics Committee

Disclosure Statement

The authors have no conflicts of interest to declare.

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Author contributions

A.K. was responsible for the design of the research project as well as data collection, annotation, analysis and write up of the findings. A.L. made important contributions to the interpretation and discussion of findings, as well as the write up of the study. All authors read and approved the final version.

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Figure Legends

Figure 1: The target structure "the orange dog", produced by participant CP6 with stress on animal (indicated by capital letters), illustrates the different annotation levels: (1) orthographic annotation including pause position, (2) position of the stressed word, (3) comments. The figure also shows the intensity contour and its range. The oscillogram (sound wave) was added for illustrative purposes.

Figure 2: Mean duration of pauses in ms for each group (TD and CP = typically-developing children and children with cerebral palsy) with regard to position (P1, P2, P3 = pause following determiner, adjective and noun respectively) and stress condition (C1 = adjective stressed, C2 = noun stressed)